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DATA AVAILABILITY TO SUPPORT A STANDARDIZED MILITARY  
GEOGRAPHICAL INFORMATION (U) CONSTRUCTION ENGINEERING  
RESEARCH LAB (ARMY) CHAMPAIGN IL R D LOZAR ET AL.

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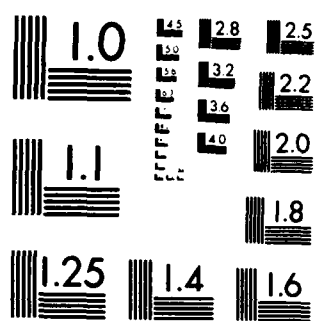
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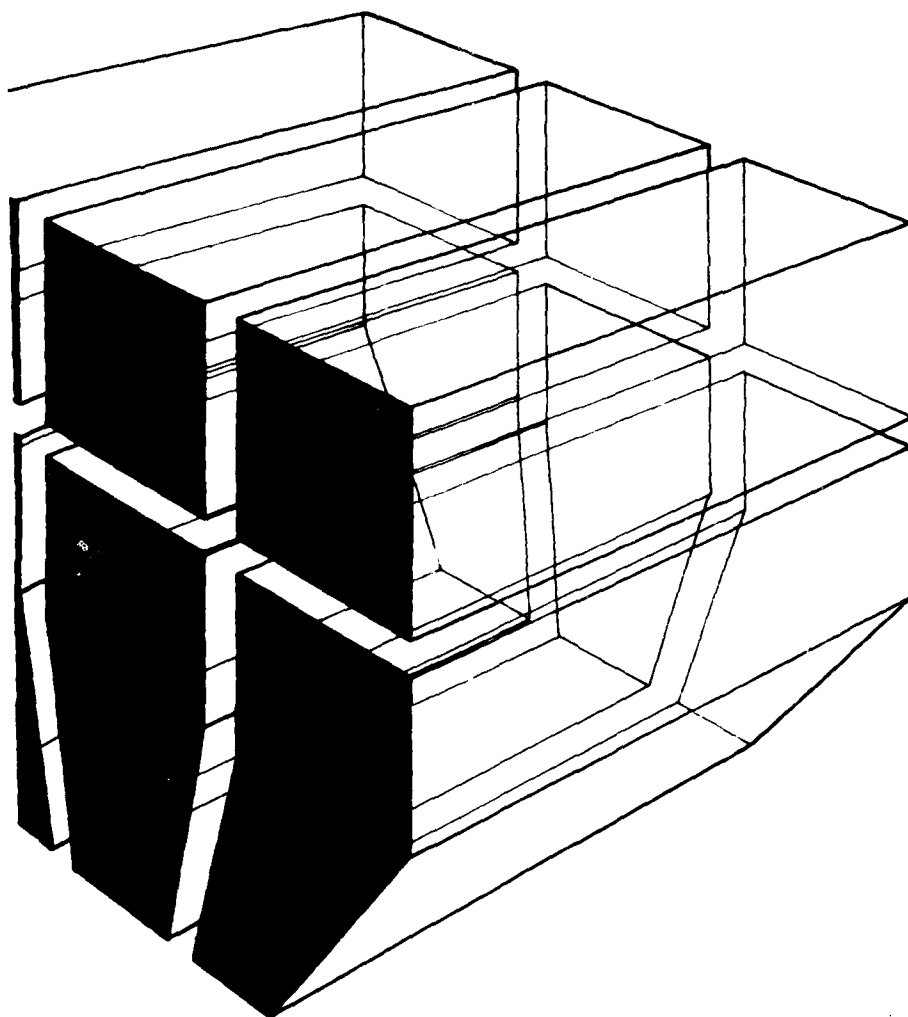
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TECHNICAL REPORT N-147  
March 1983  
Environmental Computer Mapping

DATA AVAILABILITY TO SUPPORT A  
STANDARDIZED MILITARY GEOGRAPHICAL  
INFORMATION SYSTEM DATABASE



by  
R. D. Lozar  
D. J. Smead

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> clarity, ease of use, and high information value. However, such data must first be available.

This study investigated a proposed standard classification scheme for computer storage and manipulation of geographical information and tested whether the proposed scheme could actually be supported by available data. The test, conducted at three National Guard installations, indicated that the scheme worked well, but that data availability depended on the data type and the test location. x

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## FOREWORD

This investigation was performed for the National Guard Bureau Operating Center at Aberdeen Proving Ground under Intra-Army Order 13-82, "Environmental Computer Mapping," DODAAC-W23R7B. The National Guard technical monitors were Mr. Patrick Kelly and Mr. James Hensley, NGB-ARI-E.

The work was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (CERL). Mr. R. Lozar was the CERL Principal Investigator. Dr. R. K. Jain is Chief of EN. COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.



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# DATA AVAILABILITY TO SUPPORT A STANDARDIZED MILITARY GEOGRAPHICAL INFORMATION SYSTEM DATABASE

## 1 INTRODUCTION

### Background

Military installations maintain large tracts of land for training and for personnel and equipment stationing. The personnel who manage these lands must have knowledge about various geographical facts (e.g., soils, water resources, geology) which pertain to their installations. Being able to get this type of information fast is essential to viable management.

During the past decade, computers have provided new methods of manipulating data; as a result, managers can now deal more effectively with resource management questions earlier in the planning process than was previously economically feasible. These new methods of data storage, retrieval, and manipulation are provided by Geographical Information Systems, a method which would be useful to military resource managers. However, support of a military-wide GIS first requires a data classification scheme which can be applied both universally and to be specific to a site.

### Objective

The objective of this study was to develop and test the practical feasibility of supporting a MACOM-level computer-adaptable data classification scheme to support a GIS for environmental protection, natural resource management, and military land use planning which would be applicable to a variety of settings.

### Approach

First, a proposed classification scheme (see Appendix) was developed. The next step was determining whether data to support the scheme was available and then obtaining the data as maps. The maps were then evaluated to see if they were in a form pertinent to supporting the proposed classification scheme.

Maps not already in a usable form were put into the classification scheme format, or the classification scheme was updated. (This step is called "preinterpretation.") The maps were then put in computer-readable form (called digitizing) and then into a form usable by a GIS. The degree of data captured in the result was evaluated.

The classification scheme was tested at three sites (Camp Roberts, CA; Camp Williams, UT; and Camp Santiago, PR) which illustrate a variety of geographical characteristics and data sources.

### Scope

The GIS concept as used here applies to early planning evaluation of locational relationships for the military's mission as it affects environmental protection, natural resource management, and land use planning. This study did not examine the applicability of GIS techniques to cantonment area master planning, construction, or building design, nor did it deal with the validity of the GIS concept for military applications.<sup>1</sup>

## 2 MILITARY USE OF A GEOGRAPHICAL INFORMATION CLASSIFICATION SCHEME

The military's stewardship of large amounts of land demands competent resource management practices, both at the installation level and at the overseeing headquarters command (the major Army commands [MACOMs] or their equivalents). Good resource management requires a knowledge of the spatial distribution of many geographical data types like vegetation, soils, etc., at each installation. Military personnel must have access to this information quickly in order to make effective management decisions.

Military installations are operated by different agencies under different regulations and in different geographic regions. As a result, data availability and the means of manipulating and analyzing it must vary widely. Even if good data about a location is available, the ability of a MACOM-level manager to allocate mission assignments among different installations is severely hampered by total lack of data, nonavailability of existing data at the MACOM where it is needed, and lack of consistency and comparability among data from different sources.

New methods of data manipulation using computers have emerged in the past decade which allow managers to deal effectively with resource management questions

<sup>1</sup> Robert Lozar and Harold Balbach, *The Environmental Early Warning System (EEWS): Concept Description*, Technical Report N-144 (U.S. Army Construction Engineering Research Laboratory [CFRL], 1983).

at an earlier stage of planning than was previously economically feasible. Such methods of mapped data storage, retrieval and manipulation are called Geographical Information Systems (GISs).

Several commercial GISs are available<sup>2</sup> and some are being developed specifically for Army needs.<sup>3</sup> These systems allow easy, inexpensive storage, update, display, and sophisticated analysis of mapped data.\* These systems are generally used to analyze single sites or a series of defined sites within a relatively defined regional area (for example, within a state). However, the Department of Defense (DOD) has a much broader problem in that a GIS it uses must deal with many sites all over the world.

GISs can be divided roughly into the manipulation portion and the data section. Manipulations are instructions (the software) written by a computer programmer which tell the computer how to handle the user-submitted instructions (i.e., the questions a user wishes to answer). The data is the information about a location (installation) which is stored for access by the software according to the user instructions. The software and data, as defined here, are usually independent of each other. Thus a good GIS, by its nature, can theoretically deal with any site in the world. However, mapped data, by nature, is location-specific.

If mapped data is location-specific, there is a need for a data classification scheme which will: (1) be consistently applicable to a worldwide variety of situations, (2) be specific enough to support resource planners' analysis questions, (3) contain the most pertinent information types for resource management purposes, (4) be versatile enough to be used for a wide variety of purposes over a long period of time, (5) be supported by data which is easily obtainable from a few centralized sources, and (6) be specific to DOD.

<sup>2</sup>ERSI *Geographic Information Software Descriptions* unpublished; (380 New York St., Redlands, CA 92373); *ERDAS 400 System Programmer's Guide* (ERDAS Inc., 999 McMillan St., N.W., Atlanta, GA 30318, 1978); Fish and Wildlife Service, *General Capabilities of MOSS* unpublished notes, (Western Energy and Land Use Team, Department of the Interior, 1978).

<sup>3</sup>Lozar, 1983.

\*This report assumes the usefulness and applicability of these capabilities to Army problems. For further details of GIS capabilities, see Lozar, 1983.

Previous studies have tried to answer some of these questions, but largely for civilian purposes.<sup>4</sup> Therefore, U.S. Army Construction Engineering Research Laboratory (CERL) personnel who had considerable experience in designing computer-readable geographical data storage (GIS databases) specific to DOD needs proposed a classification scheme which would satisfy these criteria (see Appendix). Seeing the usefulness of the GIS concept, the Environmental Resources Branch of the National Guard Bureau (NGB-ARI-E) wanted to obtain computer-readable forms of environmentally pertinent maps of three of its installations: Camp Roberts, CA; Camp Santiago, PR; and Camp William, UT.

Camp Roberts, CA, is located on the edge of the Santa Lucia Mountains bordering the Salinas River. The climate is semi-dry Mediterranean type. Low hills border narrow, flat valleys where naturally ephemeral streams run. Camp Santiago is near the southern coast of Puerto Rico. It extends from the flat coastal plain on the south to low hills on the north. Climate is seasonally dry, semi-tropical. Camp Williams, UT, is located west of the Jordan River about 15 miles south of Salt Lake City. The installation topography is gently rolling, and it is located in a very dry climate. The variety of these locations provided CERL with an opportunity to test the proposed classification system at different geographical areas.

### 3 DESIGN OF A CLASSIFICATION SCHEME

Because of the enhanced capabilities that computer manipulation allows, the design of the database (the maps and the categories that different items on a map fall into) that a GIS works from to generate a map will not be the same as one normally used to generate a published paper map. The major, unique considerations in the design of a GIS database classification scheme are: (1) storage economy, (2) use of implication strategy, (3) use of "raw" data, (4) nonstandardizable maps, (5) standardizing nonstandardizable maps.

<sup>4</sup>Soils Staff at the Soil Conservation Service, *Soil Taxonomy*, Agricultural Handbook #436 (U.S. Department of Agriculture, December 1975); James R. Anderson, Ernest E. Hardy, John T. Roach, and Richard E. Witmer, *A Land Use and Land Cover Classification System for Use With Remote Sensor Data*, Geological Survey Professional Paper 964 (U.S. Government Printing Office, 1976).

(6) useful maps, (7) double-decking maps, and (8) computer-generated data.

### **Storage Economy**

Storage economy is often equivalent to cost economy, either in case of use or financial economy. Before using or developing a GIS, one must first decide how big the database can potentially be. (In the proposed classification scheme, 30 maps will be stored, each with 15 different uniquely identified items called categories.) Consistency is a prerequisite for this step because the manipulation part of a GIS can work with the data only if it follows the parameters defined for the database. The larger the database, the more costly storage will be, and the slower will be the search, display, and manipulation for the computer. Since this classification is limited to 30 maps, each with no more than 15 possibilities, the resulting 450 total possibilities must be as descriptive (i.e., as "information-rich" or "information-dense") as possible. The development of the scheme given in the Appendix therefore was approached by answering the following questions:

1. What data types does a resource manager need?
2. What sources are available?
3. How should the information be classified?

### **Use of Implication Strategy**

Use of implication strategy is a major factor in designing the classification scheme. This means that if one type of data directly implies another type, then there is no need to store both; i.e., storage economy is increased by decreasing the amount of information which must be stored. Instead, to use the second data type, call up the first (which is stored), reinterpret it, and then display or manipulate it. The most common example of this is soil types, which imply other data types (permeability, land forms, fertility, construction characteristics, etc.). Thus, when soil types are stored, they can be reinterpreted to determine good housing development or tracked vehicle training areas. An extension of the implication strategy is that a combination of two or more stored data items can be used to infer a third. For example, a forester in the southeastern United States who knows a tree type and its height can make an intelligent guess of its age. Such inferences are common daily occurrences in giving professional opinions and are important in computer data handling and storage. The CERL scheme has been designed to be implication-rich.

### **Collection of "Raw" Data**

Raw data (data which has fewest subjective interpretations applied) is the best type for collection and storage because it is the most information-rich, and because the implication strategy can be applied to it with greater versatility than for any other type. For example, if "soil types" are stored, it is easy to infer permeability. However, if "soil permeability" is stored, it would be impossible to generate or infer with any validity "soil type," "land form," "fertility," "construction characteristics," etc. The definition of "raw data" is opportunistic and therefore not clearly standardized. It depends on the maps or data available.

### **Nonstandardizable Maps**

The proposed scheme is not completely standardized in cases where the raw data cannot be put in a simple scheme of 15 categories and in cases where its specificity and implication richness make it too valuable to do without. For example, the Soil Conservation Service (SCS) Soil Series classification is so important that the entire original survey is stored independent of a standard classification scheme. Although this makes it more difficult to display, manipulate, and store, it is clearly worth the effort.

### **Standardizing Nonstandardizable Maps**

To decrease the effects of departures from standard classification schemes, alternatives have been developed using the "implication" strategy. The nonstandard data is reinterpreted into similar useful categories which can be standardized. For example, in this scheme, the SCS Soil Series have been reinterpreted into the Unified Soils classification maps (Maps 5.1) and into the Land Forms/Geology maps (Maps 6.1). Each of these is more general than the original, but with proper use, they are information- and implication-rich. In fact, combining the Unified Soils and Land Forms maps with topographic slope, aspect, and vegetation would generate a map somewhat similar to the SCS Soils map.

### **Useful Maps**

Sometimes a map is potentially so useful that even though it could be inferred from other data, it is worth saving. For example, the SCS Soils map directly implies the Land Form/Geology map; however, land forms can imply fertility, engineering properties, stability, soil types, permeability, etc. Thus, if this type of data is likely to be used often, it should be saved so that it will not have to constantly be reinterpreted.

### Double-Decking Maps

If a computer is told that every map will contain 15 categories, but only five will be used on a particular map, then the potential use of 10 other categories is being wasted. If the five categories will cover the entire study area, then there is no greater detail available. However, the five categories may cover only a portion of the study area (e.g., in the case of "commercial forest type"). In this case, the user will know that there will be no commercial forests within urbanized (cantonment) areas, so there will always be a blank area in urbanized locations. This means that the "left-over" categories can be used for data that might apply only to urbanized areas (e.g., whether buildings are classified as permanent, semipermanent, or temporary). In the proposed classification scheme, the map called "3.4 - Vegetative Age and Permanence of Cantonment Structures" is designed in just this "double-decking" manner.

Exactly the opposite procedure can also be used to advantage. If a map (e.g., firing ranges, safety fans) will take more than 15 categories, so that it is stored in two or more locations or files in the computer, two uses which normally overlap can be put in separate files. This will make display output cleaner and easier to interpret. Since the GIS can combine the files easily, the amount of original data available for manipulation is preserved.

### Computer-Generated Data

Highly useful maps can often be generated from previously stored maps far more easily than they can be digitized\* from an existing map. This is not the same as reinterpreting and combining categories using implication strategy. Instead, separate computer programs are written to specifically manipulate a map into the correct format. For the CERL scheme, specific computer programs were written to generate the Slope and Aspect maps from a Topographic Elevation map, a Distance from Installation Boundary map from the Installation Boundary map, and the Distance from Roads map from the Lines of Communication map. These basic criteria guided the design of the computer classification scheme.

## 4 DATA FOR THE CLASSIFICATION SCHEME

The data needed to support the classification system had to be available from a few centralized sources.

\*Digitizing means to put into computer-readable form.

rather than field-collected. Otherwise, the cost of collecting new data would make the preparation and digitizing of maps much too expensive.

### Civilian and Military Source Characteristics

Both civilian and military information sources were used for the classification scheme. Civilian sources are often characterized as more general in nature, but professionally done and standardized. The U.S. Geological Survey topographic quadrangle sheets are examples. However, they rarely deal with questions that are military-specific and, when comparing map themes (e.g., geology vs. urbanized land use), they are rarely coordinated in either the level of detail they present or their scale.

Military sources are usually far more detailed and deal with military-specific questions. However, since it is not a major mission of most DC agencies to produce maps, there may be variations in level of detail, or certain necessary data may not have been collected. This adds to the problems of developing a standardized database. Fortunately, agencies such as the Engineering Topographic Laboratory (ETL) and the Defense Mapping Agency (DMA) generate high-quality geographical military support materials. CERL surveys<sup>5</sup> have identified the best potential sources.

### Sources

Generally, the sources listed below provided the most useful support for the proposed data classification scheme. When developing a comprehensive data file, these sources should be contacted immediately to gather data about a particular military installation.

1. Earth Resources Observation System (EROS) Data Center: provides NASA aircraft (high-altitude) color infrared aerial photographs which support land use and vegetation density interpretation.

2. Engineering Topographic Laboratory *Terrain Analysis Studies*: provide a wide series of basic planning data.

3. U.S. Geological Survey topographic quadrangle maps: provide basic data in areas such as roads and streams, some land use, and vegetation distribution interpretation.

<sup>5</sup>Robert C. Lozar, J. Robert Anderson, and Harold E. Balbach, *Data Requirements for Army Land Use Planning and Management*, Interim Report N-55/ADA062599 (CERL, 1978); William Goran, *Water Quality Data for Army Military Installations*, Technical Report N-63/ADA067253 (CERL, 1979).

4. Defense Mapping Agency: provides the digitizing of the topographic elevation information.

5. Soil Conservation Service (county or national offices): provides soil series maps and interpretations of a soil's potential restrictions.

6. Installation Environmental Impact Statements: provide wildlife habitat, significant vegetation types, and particular environmental considerations.

7. Installation Master Plans: provide land uses, cantonment area detail, utilities, structure permanence, and future plans.

8. Installation personnel: provide detailed or current information for forestry programs, range, and maneuver areas, and data which are not available from other sources.

9. Various state agencies: provide water quality standards, land uses, etc.

10. CERL, the Army Environmental Hygiene Agency (AEHA), and other research organizations: provide special installation surveys, such as noise levels, water pollution levels, air quality standards, etc.

#### Data Accuracy

Based on information from previous studies about the type of data needed for resource management,<sup>6</sup> the sources used for this scheme were the best available from relatively centralized data storage and distribution agencies. Depending on the source, data quality and level of detail vary. For example, soil series maps have details as small as a few acres, while the "wildlife suitability maps" give only a broad indication of the existing situation.

In translating information from published map form to computer form (Figure 1), some accuracy is lost. This results from the resolution\* of the equipment

<sup>6</sup>Robert C. Lozar, et al., 1978; William Goran, 1979.

\*Resolution is the accuracy with which a location can be determined. 1/100th of an inch on a map using CERL's automatic digitizer.

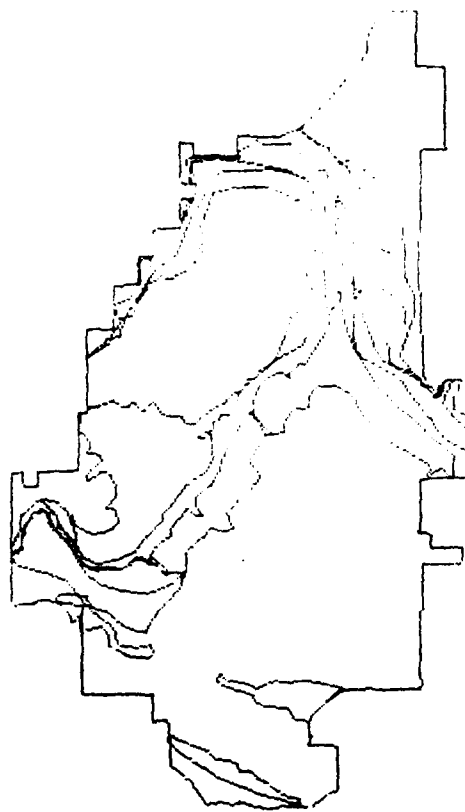


Figure 1. Digitized, unfinished data. Camp Roberts soils.

used and the computer storage efficiency desired (the smallest amount of change deemed worth saving). Sometimes the resolution might not be sufficient (for example, the level of detail may not be great enough to give the exact location of a road). Normally, however, the computer storage ability provides greater accuracy than that presented in the original mapped data. For example, soil locations on the map are defined by sharp lines; however, in reality, soils normally grade smoothly from one type to another.

For this scheme, data was always digitized from the published data sources at the source's limit of precision and stored at that degree of detail. However, for normal display (Figure 2) and manipulation (Figure 3), the resolution adopted (1 hectare) is considered sufficient for most maps at standard scales and is almost indistinguishable from the original in detail when the original had a scale of 1:2000 or larger.

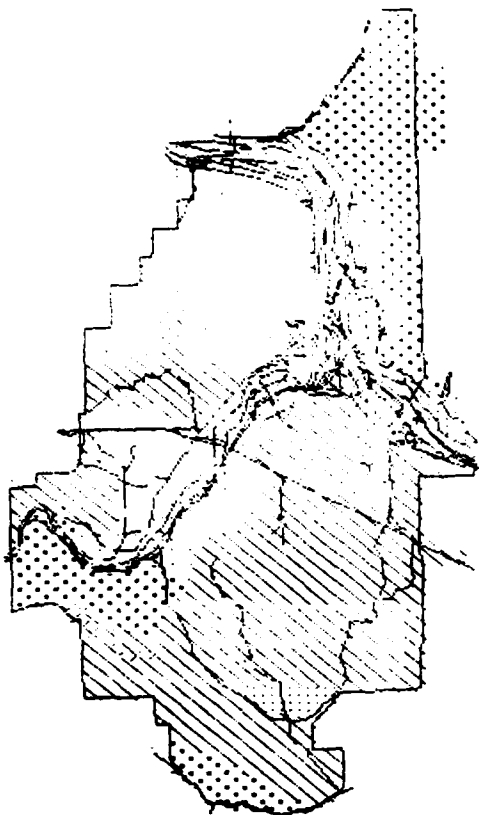


Figure 2. Display of digitized data with base map.

## 5 DATA COLLECTION AND TESTING OF THE CLASSIFICATION SCHEME

The applicability of the classification scheme was tested at the three National Guard installations to develop a compromise between design optimization and the restraints of data availability. The test was conducted at three geographically diverse installations: Camp Roberts, CA; Camp Williams, UT; and Camp Santiago, PR.

In this test of the classification scheme using the proposed sources, a wide variety of situations were encountered. Because the ETL's terrain analysis for Fort Ord includes data on Camp Roberts, that installation's database was the most complete, consistent, and standardized. Other data sources of good quality were also found (e.g., Puerto Rico's land use maps and



Figure 3. Data used in manipulations (same as Figure 2 without base map).

Army Environmental Hygiene Agency noise studies). This information proved useful and showed that the scheme was appropriate for these sources. However, for some data that materialized and for which the proposed categories were useful, the scheme still was not adequate. For example, in the water quality classification categories which states give major water bodies, several categories occurred at the same location. The scheme cannot efficiently handle such a problem, and no solution can be recommended at this time.

The following sections provide an overview of the data sources and interpretation procedure. The information is presented in sections that correspond to the format used to generate the maps. The overview points out the major findings for each map. The parenthetical numbers after each section title indicate the number of the map generated. Tables 1, 2, and 3 provide a detailed description of each installation.

**Table 1**  
**Camp Roberts, California**

Word Description	Map No.	Source Used	Ease of Getting Data	Preinterpretation Holds Data Value Well	Quality of Data Received	Data Richness	Classification Scheme Adequate	Is It Computer Generated?	Is It Derived Using Implication?
Boundary/ Distance from Boundary	1.1	terrain analysis	good	yes	good	high	yes	no/yes	no
Watersheds	2.1	USGS topo	good	yes	good	low	no; not standardized	no	no
Water Resources	2.2	USGS topo	good	yes	good	high	yes	no	no
Water Production	2.3	terrain analyses	good	yes	good	high	yes	no	no
Water Use/ Leases	2.4	states/ none	fair/-	no/-	fair/-	low/-	no/-	no/no	no/no
Distance from Streams	2.5	2.2	good	yes	good	high	yes	yes	no
Land Use	3.1	terrain analysis	fair	fair	fair	fair	fair	no	no
Veg. Type/ Density	3.2	terrain analysis	good	yes	good	high	yes	no	no
Veg. Height/ Utilities	3.3	none terrain analysis	-/good	-/fair	-/fair-poor	-/low	-/fair	no	no
Veg. Age/ Cantonment Permanance	3.4	none/none	-/-	-/-	-/-	-/-	-/-	no/no	no/no
Transportation	3.5	USGS topo & terrain analysis	good	yes	good	high	yes	no	no
Dist. from Roads	3.6	3.5	good	yes	good	high	yes	yes	no
Training Areas	4.1	instal- lation	good	fair	fair	low	yes	no	no
Ranges	4.2	instal- lation	good	fair	fair	low	yes	no	no
Cross Country Improvement	4.3	terrain analysis	good	yes	good	high	fair	no	no
Unified Soils	5.1	5.2 & ETIS	good	yes	good	high	yes	yes	yes
SCS Soils	5.2	SCS	good/fair	yes	fair	high	not intended to be standardized	no	no



**Table 1 (Continued)**  
**Camp Roberts, California**

Word Description	Map No.	Source Used	Ease of Getting Data	Preinterpretation	Quality of Data Received	Data Richness	Classification Scheme Adequate	Is It Computer Generated?	Is It Derived Using Implication?
				Holds Data Value Well					
Landforms	6.1	terrain analysis	good	yes	good	medium	yes	no	no
Topo Eleva.	7.1	none	—	—	—	—	—	—	—
Topo Slope	7.2	—	—	—	—	—	—	—	—
Topo Aspect	7.3	—	—	—	—	—	—	—	—
Wildlife & Flora	8.1	SCS/ETIS	fair	fair	good	medium	yes	no	yes
Noise	9.1	none	—	—	—	—	—	no	no

**Table 2**  
**Camp Williams, Utah**

Word Description	Map No.	Source Used	Ease of Getting Data	Preinterpretation	Quality of Data Received	Data Richness	Classification Scheme Adequate	Is It Computer Generated?	Is It Derived Using Implication?
				Holds Data Value Well					
Boundary/ Distance from Boundary	1.1	Installation map	fair	yes	fair	medium	no; need to identify various ownerships	no/yes	no
Watersheds	2.1	Installation map	good	yes	good	medium	no; not standardized	no	no
Water Resources	2.2	Installation map	good	yes	good	high	yes	no	no
Water Production	2.3	None	—	—	—	—	—	—	—
Water Use/ Leases	2.4	States/none	fair/—	no/—	fair/—	low/—	no/—	no/—	no/—
Distance from Streams	2.5	2.2	good	yes	good	high	yes	yes	no
Land Use	3.1	None	—	—	—	—	—	—	—
Veg. Type/ Density	3.2	None/none	—/—	—/—	—/—	—/—	—/—	—/—	—/—
Veg. Height/ Utilities	3.3	None/none	—/—	—/—	—/—	—/—	—/—	—/—	—/—
Veg. Age/ Cantonment Permanance	3.4	None/none	—/—	—/—	—/—	—/—	—/—	—/—	—/—

Table 2 (Continued)  
Camp Williams, Utah

Word Description	Map No.	Source Used	Ease of Getting Data	Preinterpretation		Data Richness	Classification Scheme Adequate	Is It Computer Generated?	Is It Derived Using Implication?
				Holds Data Value Well	Quality of Data Received				
Transportation	3.5	Installation/Map	good	yes	good	high	yes	no	no
Dist. from Roads	3.6	3.5	good	yes	good	high	yes	yes	no
Training Areas	4.1	Installation	fair	yes	poor	low	yes	no	no
Ranges	4.2	Installation	fair	yes	poor	low	yes	no	no
Cross Country Improvement	4.3	None	—	—	—	—	—	—	—
Unified Soils	5.1	5.2 & ETIS	good	yes	good	high	yes	yes	yes
SCS Soils	5.2	SCS	good	yes	fair	high	not intended to be standardized	no	no
Landforms	6.1	SCS general description	good	yes	good	medium	yes	yes	yes
Topo Eleva.	7.1	None	—	—	—	—	—	—	—
Topo Slope	7.2	7.1	—	—	—	—	—	—	—
Topo Aspect	7.3	7.1	—	—	—	—	—	—	—
Wildlife and Flora	8.1	SCS ETIS	fair	fair	good	medium	fair	yes	yes
Noise	9.1	None	—	—	—	—	—	no	no

Table 3  
Camp Santiago, Puerto Rico

Word Description	Map No.	Source Used	Ease of Getting Data	Preinterpretation		Data Richness	Classification Scheme Adequate	Is It Computer Generated?	Is It Derived Using Implication?
				Holds Data Value Well	Quality of Data Received				
Boundary/Distance from Boundary	1.1	USGS topo	good	yes	good	high	yes	no/yes	no
Watersheds	2.1	USGS topo	good	yes	good	medium	no; not standardized	no	no
Water Resources	2.2	USGS topo	good	yes	good	high	yes	no	no
Water Production	2.3	none	—	—	—	—	—	—	—

**Table 3 (Continued)**  
**Camp Santiago, Puerto Rico**

Word Description	Map No.	Source Used	Preinterpretation		Quality of Data Received	Data Richness	Classification Scheme Adequate	Is It Computer Generated?	Is It Derived Using Implication?
			Ease of Getting Data	Holds Data Value Well					
Water Use/Leases	2.4	None/none	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Distance from Streams	2.5	2.2	good	yes	good	high	yes	yes	no
Land Use	3.1	Land use maps	fair	fair	good	high	fair	no	no
Veg. Type/Density	3.2	None/none	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Veg. Height/Utilities	3.3	None/none	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Veg. Age/Cantonment Permanance	3.4	None/none	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Transportation	3.5	USGS topo	good	yes	good	high	yes	no	no
Dist. from Roads	3.6	3.5	good	yes	good	high	yes	yes	no
Training Areas	4.1	None	—	—	—	—	—	—	—
Ranges	4.2	None	—	—	—	—	—	—	—
Cross Country Improvement	4.3	None	—	—	—	—	—	no	no
Unified Soils	5.1	5.2 & ETIS	good	yes	good	high	yes	yes	yes
SCS Soils	5.2	SCS	good	yes	good	high	not intended to be standardized	no	no
Landforms	6.1	SCS general description	good	yes	good	medium	yes	yes	yes
Topo Eleva.	7.1	—	—	—	—	—	—	—	—
Topo Slope	7.2	7.1	—	—	—	—	—	—	—
Topo Aspect	7.3	7.1	—	—	—	—	—	—	—
Wildlife and Flora	8.1	SCS ETIS	fair	fair	good	medium	fair	yes	yes
Noise	9.1	U.S. Army Environmental Hygiene Agency	good	yes	good	medium	yes	no	no

### **Installation Boundary (1.1)**

Only the first category (Installation Boundary) of this map was digitized into computer-readable form. The remaining categories are produced by a "distance from" determination computer program (see Chapter 4). The sources used to generate this map may include the U.S. Geological Survey (USGS) topographic maps, ETL terrain analysis maps, and in some cases, the installation.

### **Watersheds (2.1)**

This classification scheme was first set up to categorize watersheds by stream order. However, this approach was not feasible. USGS land use/land cover drainage basin data was either not available or not detailed enough for the installations in this study. Instead, the drainage basins were defined according to their association with a named stream on a USGS 1:24,000-scale topographic quadrangle map, regardless of the stream order of their rivers. Contour lines on the USGS map were used to define the ridges of the drainage basins. Therefore, no standardized categories are recommended for this map.

### **Water Resources (2.2)**

Stream ordering and water bodies are easily determined from standard USGS quadrangle maps or other similar sources (e.g., DMA "Special Installation" maps). However, much of the western United States and Puerto Rico is characterized by intermittent rather than permanent streams; therefore, the generally accepted method of stream ordering (developed after Strahler<sup>7</sup> and clearly most applicable for the Eastern United States) was not very useful in these study areas. As a result, most of the mapped area was classified as either intermittent or ephemeral. Only permanent streams were classified according to their orders. Both Camp Williams and Camp Santiago have canals, so a category of "man-made ditches/canals" was added to the classification scheme.

### **Water Production (2.3)**

A water production map is available only if an ETL terrain analysis has been completed, as at Camp Roberts. The other two installations did not have a terrain analysis prepared.

### **State Water Use/Water Quality Classification and Land Leases (2.4)**

Many states have water use classifications. However, there are several problems in obtaining and storing this data: (1) not all states have prepared this type of data, (2) the responsible agency is not always easily identified or contacted, (3) the information density is usually very low (at an installation, only a few, if any, major streams have a state classification), (4) a stream is usually classified under multiple categories, which decreases the ease of storage and interpretability of the map, and (5) state classifications vary. Despite these problems, these use classifications were included because they are so environmentally important.

Inclusion of leased land makes this map an example of a "double-decker" map. Leased land locations and classified stream use will not overlap, because the former is data of an area type, while the latter is linear; further, both classifications occur only rarely. Leased land information is available only from the installations.

### **Distance From Streams (2.5)**

This map is generated from the Water Resources map, using the "distance from" computer program.

### **Land Use (3.1)**

Data for the land use maps was obtained from several sources, including ETL terrain analysis maps and state land use maps. If a land use map of an area has been done, this does not necessarily mean that one for an installation within that area is available. For example, at Camp Santiago, a land use map of the area did not include the installation, so this information had to be requested specifically.

The installation master plan is a helpful data source for greater detail in developed or cantonment areas. However, master plans for the installations studied were not used. Instead of master planning documents, high-altitude photos were used to develop information on vegetation distribution and density, agricultural uses, roads, and urbanized uses.

Although some installation land use maps were available for Camp Roberts, it is often critical for environmental impact purposes to know the adjoining nonmilitary uses. Incompatibilities may occur, particularly along the boundary between military and civilian land uses. These nonmilitary land uses may only be available through interpretation of the USGS quadrangle maps, USGS land use/land cover maps (if

<sup>7</sup>A. N. Strahler, "Quantitative Analysis of Watershed Geomorphology," *Transactions of the American Geophysical Union*, Vol. 38, No. 6 (1957), pp 213-220.

available), and aerial photography. On the whole, land use information is difficult to collect and is usually determined by combining several sources, none of which are easily standardized.

#### **Vegetation Type/Density (3.2)**

Sometimes vegetation maps are available (e.g., the terrain analysis for Camp Roberts). The vegetation and land use maps are often similar (Camp Santiago). Aerial photos can sometimes be useful for determining vegetation density; however, most of the time, this data is not available.

#### **Vegetation Height and Utilities (3.3)**

Vegetation masses and utilities are not usually located in the same place, so a "double-decker" map is generated for this category. Vegetation height information may be available from the installation forester, while utilities data can be obtained from the installation master plan. Neither source was available for any installation in this study; however, some utility data was available for Camp Roberts in the ETL terrain analysis studies.

#### **Vegetative Age and Permanence of Cantonment Structures (3.4)**

Vegetative age and permanence of cantonment structures are examples of a "double-decker" map. The sources used to generate the map are the same as those used for vegetation height and utilities; however, these sources were not available for the installations in this study.

#### **Transportation/Lines of Communication (3.5)**

USGS topographic quadrangle maps and terrain analysis maps are adequate sources of transportation information. For greater detail, installation master plans are useful because they are of a larger scale. This is especially helpful for the categories of airfields, airstrips, and helicopter landing zones. For this study, topographic maps were used for all installations. The ETL terrain analysis map, which indicates airfields, airstrips, and helicopter landing zones, was available only for Camp Roberts.

#### **Distance From Roads (3.6)**

This map was generated from Map 3.5—lines of communication.

#### **Ranges (4.1)**

Firing range maps are usually available from the installations, but vary in quality and detail. Because ranges are such an important part of an installation

and because they differ so greatly, the data was stored in two computer maps (files) totaling 30 different categories rather than the usual 15 categories. Usually firing range safety fans of the same or similar types overlap each other, making the data display harder to interpret. Placing data on two maps makes interpretation easier and preserves the information needed for manipulation and analysis.

#### **Maneuver and Other Noncantonment Uses (4.2)**

This information is usually available from the same sources and in the same form (often on the same map) as the ranges data.

#### **Cross Country Movement (4.3)**

This map is important for setting up military training, but data to generate it is available only in the ETL terrain analysis studies. For this study, such data was available only for Camp Roberts. A GIS can combine and manipulate some of the other maps in this database to generate a similar result. However, the categories used in the CERL scheme are taken directly from the ETL terrain analysis study. Therefore, a GIS-generated map would not necessarily be similar.

#### **Predominant Unified Soils Type (5.1)**

This map can be generated from SCS soils-survey maps and the Form-5 sheets.\* These sources were available for the installations studied. Unified Soils can be found in the "Estimated Engineering Properties of Soils" portion of a soil survey and in the first section of a Form-5 sheet. No interpretation was necessary for most of the soils because the classification scheme's categories corresponded exactly to the texture's listed in the Unified Soils. However, there was a problem with classifying soil complex areas. Since a soil complex is a mixture of two or more soils, its depth and stratification do not correspond to the categories in the proposed scheme. Simply calling them "complex" would add no information. The most acceptable solution to this problem is to use the dominant soil in the complex layer.

#### **Soil Conservation Service—Soils Types (3.2)**

SCS offices can provide soil maps. Published surveys for counties are available from state offices. County offices can provide preliminary information such as unpublished maps and Form-5 sheets. The ETL terrain

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\*Form-5 sheets are condensed fact sheets for each soil series. They include a general soils description, engineering uses, wildlife habitat suitability, and potential vegetation.

analysis for Camp Roberts contained the more general Soils Associations map. This map was superseded when the detailed Soil Series maps became available from the counties.

#### **Land Forms/Geology (6.1)**

SCS provided general descriptions for soil types; these were interpreted and used to generate a land forms map. This map describes the underlying parent material or process for each soil. Planning books which consider geology<sup>8</sup> can be used to answer questions about these categories. However, because land forms categories are broad classifications, it was not uncommon in this study to have large areas of the installations identified as only a few land form types.

#### **Topographic Elevation (7.1)**

Topographic elevation data can be obtained easily but is difficult and slow to digitize. At the request of a DOD agency, DMA will digitize this information for installations without charge. However, it may take several months or years to get this data for an installation. Data for all the study areas in this research project will be digitized at DMA.

#### **Topographic Slope (7.2)**

A topographic slope map can be computer-generated once the elevation data is available in the correct form.

#### **Topographic Aspect (7.3)**

A topographic aspect map can be computer-generated once elevation data is available in the correct form.

#### **Wildlife and Flora (8.1)**

Four of the classification scheme's 13 categories were designated for wildlife habitat suitability: open-land wildlife, woodland wildlife, wetland wildlife, and rangeland wildlife. The best source of this information is the SCS Form-5 sheets. If these are not available, soil descriptions and the "Use of Soils for Wildlife" portion of the county soil survey are helpful, but are much more general.

Wildlife habitat suitability has four ratings when Form 5 sheets are used: good, fair, poor, and very

poor. For this map, the categories "good" and "fair" indicate potential habitat. In the case of soil complexes, a "fair" rating was allowed. However, one problem was that an SCS determination of woodland suitability is based on harvestable wood rather than on vegetative type. Therefore, this data had to be checked for completeness against a USGS topographic map, a terrain analysis map, and/or air photos which showed actual vegetation distribution.

#### **Noise Zones (9.1)**

The only source for generating a noise map was a Government report<sup>9</sup> about environmental noise assessment and military operations at Camp Santiago. Although the CERL Acoustics Research Team is another possible source of information, particularly for major Army installations, CERL had no noise data for the installations in this study.

## **6 CONCLUSIONS AND RECOMMENDATIONS**

A classification scheme for computer storage of geographical information was developed and tested for three locations with varying environments and types of data availability. The results of the test established the practical feasibility of supporting a MACOM-level computer adaptable classification scheme for environmental analysis. This approach could be applied consistently to a large variety of individual settings. The format presented for data and classification was analyzed, and it was found that only minor changes were needed. Uniformity and availability of data from diverse sources continue to be problems inherent in this type of classification effort. However, the sources suggested in this report are very useful and should be contacted early in the analysis process.

It is recommended that the classification scheme outlined in this report be used by personnel at MACOM (or equivalent) offices to help with environmental planning and analysis.

<sup>8</sup>Douglas Way, *Terrain Analysis: The Guide to Site Selection Using Photographic Interpretation* (Dowdin, Hutchinson, & Ross, Inc., 1973), pp 75-356.

<sup>9</sup>*Environmental Noise Assessment*, Report No. 52-34-0707-81 (U.S. Army Environmental Hygiene Agency, July 1981).

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## APPENDIX: DETAILED PRELIMINARY DATABASE CLASSIFICATION

### Map 1.1 Installation Boundary

#### Category 1. Installation Boundary

Category 2. 1 Cell Distance from Boundary--  
Within the Installation

Category 3. 2 and 3 Cells from Boundary--  
Within the Installation

Category 4. 4 and 5 Cells from Boundary--  
Within the Installation

Category 5. 6 and 7 Cells from Boundary--  
Within the Installation

Category 6. 8 and 9 Cells from Boundary--  
Within the Installation

Category 7. 10 and 11 Cells from Boundary--  
Within the Installation

Category 8. 12 or More Cells from Boundary--  
Within the Installation

Category 9. 1 Cell Distance from Boundary--  
Outside the Installation

Category 10. 2 and 3 Cells Distance from Bound-  
ary--Outside the Installation

Category 11. 4 and 5 Cells Distance from Bound-  
ary--Outside the Installation

Category 12. 6 and 7 Cells Distance from Bound-  
ary--Outside the Installation

Category 13. 8 and 9 Cells Distance from Bound-  
ary--Outside the Installation

Category 14. 10 and 11 Cells Distance from  
Boundary--Outside the Installation

Category 15. 12 or More Cells Distance from  
Boundary--Outside the Installation

### Map 2.1 Watersheds

Watersheds are identified according to named  
streams from a USGS 1:24,000-scale quadrangle map.

### Map 2.2 Water Resources

Category 1. Intermittent/Ephemeral

Category 2. First-Order Stream

Category 3. Second-Order Stream

Category 4. Third-Order Stream

Category 5. Fourth-Order Stream

Category 6. Fifth Order-Stream and Greater

Category 7. Reservoir/Pond

Category 8. Ocean

Category 9. Swamp

Category 10. Marsh

Category 11. Man-Made Ditch/Canal

Category 12. Well

Category 13. Spring

### Map 2.3 Water Production

Category 1. Surface Water Perennially Plentiful:  
Enormous to Large

Category 2. Surface Water Perennially Plentiful:  
Moderate

Category 3. Surface Water Seasonally Plentiful:  
Enormous to Large

Category 4. Surface Water Seasonally Plentiful:  
Moderate

Category 5. Surface Water Scarce: Small

Category 6. Surface Water Scarce: Meager

Category 7. Groundwater Generally Plentiful:  
Enormous

Category 8. Groundwater Generally Plentiful:  
Very Large

Category 9. Groundwater Generally Plentiful:  
Large



Category 10. Groundwater Generally Plentiful: Moderate

Category 11. Groundwater Locally Plentiful: Enormous to Very Large

Category 12. Groundwater Locally Plentiful: Large

Category 13. Groundwater Locally Plentiful: Moderate

Category 14. Groundwater Scarce: Small

Category 15. Groundwater Scarce: Meager

**Map 2.4 State Water Use/Water Quality Classification and Land Leases**

Category 1. Potable Water

Category 2. Recreation

Category 3. Aquatic and Wildlife

Category 4. Agricultural

Category 5. Industrial

Category 6. Special Use

Category 7. Leased to Public Use by DOA

Category 8. Leased to DOA

**Map 2.5 Distance From Streams**

Fifteen categories of increasingly greater distance.

**Map 3.1 Land Use (Part 1 of 3)**

Category 1. Household Units

Category 2. Transient Lodgings

Category 3. Retail Trade—General Merchandise

Category 4. Retail Trade—Food/Eating/Drinking

Category 5. Governmental Services

Category 6. Inert Materials

Category 7. Major Intersections/Interchanges

Category 8. Underground Pipelines

Category 9. Landfill

Category 10. Borrow Pit/Quarry/Mine

Category 11. Archaeological

Category 12. Forest—Commercial

Category 13. Forest—Commercial/Training

Category 14. Forest—Noncommercial

**Map 3.1 Land Use (Part 2 of 3)**

Category 1. Group Quarters

Category 2. Personal Services

Category 3. Educational—Dependent Children

Category 4. Medical, Safety, Other

Category 5. Chemicals and Allied Industries

Category 6. Chemicals Distribution and Storage

Category 7. Parking

Category 8. Aircraft Transportation

Category 9. Gate

Category 10. Industrial/Commercial Complex

Category 11. Parks

Category 12. Cemetery

Category 13. Historical

**Map 3.1 Land Use (Part 3 of 3)**

Category 1. Mobile Homes

Category 2. Repair and Maintenance

Category 3. Professional Services/Offices

Category 4. Educational—Adult Army

Category 5. Perishables, Storage

Category 6. Communications

Category 7. Sewage Plant

- Category 8. Mixed or Built-up
- Category 9. Recreational Activities
- Category 10. Crop Land
- Category 11. Pasture
- Category 12. Orchards, Groves, Vineyards, Nurseries, etc.
- Category 13. Other Agriculture
- Category 14. Reservoirs
- Category 15. Barren and Exposed Rock

**Map 3.2 Vegetation Type/Density**

- Category 1. Forest: Coniferous: Medium to Dense
- Category 2. Forest: Coniferous: Open to Medium
- Category 3. Forest: Deciduous: Medium to Dense
- Category 4. Forest: Deciduous: Open to Medium
- Category 5. Forest: Mixed: Medium to Dense
- Category 6. Forest: Mixed: Open to Medium
- Category 7. Scrub: Coniferous: Medium to Dense
- Category 8. Scrub: Coniferous: Open to Medium
- Category 9. Scrub: Deciduous: Medium to Dense
- Category 10. Scrub: Deciduous: Open to Medium
- Category 11. Scrub: Mixed: Medium to Dense
- Category 12. Scrub: Mixed: Medium to Dense
- Category 13. Grass: Short
- Category 14. Grass: Tall
- Category 15. Agriculture
- (Category 16. Open = Blank)

**Map 3.3 Vegetative Height and Utilities**

- Category 1. Less than 2 Feet
- Category 2. 2 to 5 Feet

- Category 3. 5 to 10 Feet
- Category 4. 10 to 20 Feet
- Category 5. 20 to 40 Feet
- Category 6. 40 to 60 Feet
- Category 7. 60 to 90 Feet
- Category 8. 90 to 120 Feet
- Category 9. Above 120 Feet
- Category 10. Mixed Heights
- Category 11. Electric Plant/Substation
- Category 12. Heating/Cooling Plant
- Category 13. Water Plant
- Category 14. Sewage Treatment Plant
- Category 15. Other Utilities in Cantonment Area

**Map 3.4 Vegetative Age and Permanence of Cantonment Structures**

- Category 1. Less than 1 Year
- Category 2. 1 to 5 Years
- Category 3. 5 to 10 Years
- Category 4. 10 to 20 Years
- Category 5. 20 to 30 Years
- Category 6. 30 to 50 Years
- Category 7. 50 to 80 Years
- Category 8. 80 to 120 Years
- Category 9. 120 to 170 Years
- Category 10. 170 to 300 Years
- Category 11. 300 Years and Greater
- Category 12. Mixed Ages
- Category 13. Permanent Cantonment Structure

Category 14. Semi-Permanent Cantonment Structures

Category 15. Temporary Cantonment Structures

**Map 3.5 Transportation/Lines of Communication**

Category 1. Four-Lane Hardtop Road

Category 2. Three-Lane Hardtop Road

Category 3. Two-Lane Hardtop Road

Category 4. One-Lane Hardtop Road

Category 5. Improved Dirt Road

Category 6. Unimproved Dirt Road/Tank Trail

Category 7. Federal Road

Category 8. State Road

Category 9. Railroad

Category 10. Airfield

Category 11. Airstrip

Category 12. Helicopter Landing Zone

Category 13. Bridge

**Map 3.6 Distance From Roads**

Fifteen categories of increasingly greater distance.

**Map 4.1 Ranges (Part 1 of 2)**

Category 1. Basic 25-m Firing Range (Basic 25-m--Corrective)

Category 2. Field Firing Range

Category 3. Record Firing Range

Category 4. Night Firing Range (Day Corrective)

Category 5. Automatic Rifle Markmanship Range (Automatic Rifle)

Category 6. Known Distance Range

Category 7. Machine Gun--10-m Range

Category 8. Machine Gun M160 Transition Range (Machine Gun Transition)

Category 9. Machine Gun M60 and M2 Field Fire (Machine Gun Field Fire)

Category 10. Hand Grenade Assault and Qualification (Hand Grenade Fragmentation)

Category 11. Grenade Launcher Course (Grenade Launcher, 40 mm)

Category 12. Recoilless Rifle Range (All Recoilless Rifle)

Category 13. Light Anti-Armor Weapon (LAW) Range (Rocket Launcher LAW)

Category 14. Anti-Armor Tracking and Live Fire Range

Category 15. Demolition, Booby Trap, and Land Mine

**Map 4.1 Ranges (Part 2 of 2)**

Category 1. Aerial Gunnery Range

Category 2. Mortar Subcaliber Training Range (Mortar Training Shell)

Category 3. Mortar Range (Mortar, Field Firing), 81 mm

Category 4. Field Artillery Scaled Range

Category 5. Field Artillery Indirect Fire Range

Category 6. Combat Pistol Range (Pistol, 45-Caliber, Revolver, 38-Caliber)

Category 7. Tank Gunnery Range 1:30 and 1:60 Scale

Category 8. Tank Gunnery Range 1:5 and 1:10 Scale

Category 9. Tank Gunnery Range (Stationary)

Category 10. Crew Combat Firing Range

Category 11. Tank Platoon Battle Run (SCC/PIT Battle Run Tables 9 and 10: a and b)

Category 12. Air Defense Firing Range (AD Missile Range)

Category 13. Air Strips

Category 14. Air Fields

Category 15. Cantonment Areas

**Map 4.2 Maneuver and Other Noncantonment Uses**

Category 1. Intensive Foot Training

Category 2. Extensive Foot Training

Category 3. Tracked Vehicle Training

Category 4. Mechanized Stream Crossing

Category 5. Drop Zone

Category 6. Landing Zone

Category 7. Firing Point

Category 8. Ammo-Dump

Category 9. Amphibious Assault

Category 10. Bivouac

Category 11. Impact and Permanent Dud Area

Category 12. Special Weapons Testing

**Map 4.3 Cross-Country Movement**

	Tank (M60)		APC (M113)		2-1/2 Ton Truck		1/4 Ton Truck		Foot	
SEASON	1	2	1	2	1	2	1	2	1	2
Category										
1	G	G	G	G	G	G/F	G	G/F	G	G
2	G	F	G	F	G	F	G	F	G	G
3	G	G/F	G	G/F	G/F	G/F/P	F/P	F	G/F	G/F
4	G	F/P	G	F/P	G/F	P/U	G/F	P/U	G	G/F
5	F		F		F/P		F/P		G/F	
6	F	F/P	F	F/P	F/P	P/U	F/P	P/U	G/F	G/F
7	G	P/U	G	P/U	F	P/U	F	U	G	P
8	F/P	P/U	F/P	F/P	P/U	P/U	P/U	F/P	F/P	
9	F	U	F	U	U	U	U	U	F	P
10	P/U	U	F/P	P/U	P/U	U	P/U	U	F/P	F/P
11	P/U	U	P/U	P/U	U	U	U	U	F/P	F/P
12	U	U	U	U	U	U	U	U	P	P

G=GOOD

F=FAIR

P=POOR

U=UNSUITABLE

ACCORDING TO ETL TERRAIN ANALYSIS DEFINITIONS

**Map 5.1 Predominant\* Unified Soils Type—Layer Number 1 (Part 1 of 2)**

Category 1. GW, Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines

Category 2. GP, Poorly Graded Gravels, Gravel-Sand Mixtures, Little or No Fines

Category 3. GM, Silty Gravels, Poorly Graded Gravel-Sand Mixtures

Category 4. GC, Clayey Gravels, Poorly Graded Gravel-Clay Mixtures

Category 5. SW, Well-Graded Sands, Gravelly Sands, Little or No Fines

Category 6. SP, Poorly Graded Sands, Gravelly Sands, Little or No Fines

Category 7. SM, Silty Sands, Poorly Graded Sand-Silt Mixtures

Category 8. SC, Clayey Sands, Poorly Graded Sand-Clay Mixtures

\*Predominant = the FIRST layer or the bulk of the TOP layer.

Category 9. ML, Inorganic Silts and Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands With Slight Plasticity

Category 10. CL, Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays

Category 11. OL, Organic Silts and Organic Silt-Clays of Low Plasticity

Category 12. MH, Inorganic Silts, Micaceous or Diatomaceous Fine Sandy or Silty Soils, Elastic Silts

Category 13. CH, Inorganic Clays of High Plasticity, Fat Clays

Category 14. OH, Organic Clays of Medium to High Plasticity

Category 15. PT, Peat and Other Highly Organic Soils

(Category 16. Various and Exposed Rock)

**Map 5.1 Predominant\* Unified Soils Type, Layer 2  
(Part 2 of 2)**

Category 1. GW, Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines

Category 2. GP, Poorly Graded Gravels, Gravel-Sand Mixtures, Little or No Fines

Category 3. GM, Silty Gravels, Poorly Graded Gravel-Sand Mixtures

Category 4. GC, Clayey Gravels, Poorly Graded Gravel-Clay Mixtures

Category 5. SW, Well-graded Sands, Gravelly Sands, Little or No Fines

Category 6. SP, Poorly Graded Sands, Gravelly Sands, Little or No Fines

Category 7. SM, Silty Sands, Poorly Graded Sand-Silt Mixtures

**\*Predominant = the SECOND layer or the bulk of the SECOND layer soils type.**

Category 8. SC, Clayey Sands, Poorly Graded Sand-Clay Mixtures

Category 9. ML, Inorganic Silts and Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands With Slight Plasticity

Category 10. CL, Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays

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Category 14. OH, Organic Clays of Medium to High Plasticity

Category 15. PT, Peat and Other Highly Organic Soils

(Category 16. Various and Exposed Rock)

**Map 5.2 Soils Conservation Service—Soils Types**  
According to soils maps available.

**Map 6.1 Land Forms/Geology (Part 1 of 2)**

Category 1. Sedimentary Rocks: Sandstone

Category 2. Sedimentary Rocks: Shale

Category 3. Sedimentary Rocks: Limestone

Category 4. Sedimentary Rocks: Interbedded Flat Lying

Category 5. Sedimentary Rocks: Interbedded Tilted

Category 6. Igneous Rocks: Granitic Intrusive

Category 7. Igneous Rocks: Basaltic and Volcanic Extrusive

Category 8. Metamorphic Rocks: Slate

Category 9. Metamorphic Rocks: Schist

Category 10. Metamorphic Rocks: Gneiss

Category 11. Glacial Till

Category 12. Glacial End Moraines

Category 13. Glacial Drumlins

Category 14. Glacial Eskers

Category 15. Glacial Kames

**Map 6.1 Land Forms/Geology (Part 2 of 2)**

Category 1. Glacial: Outwash

Category 2. Glacial: Lake Beds

Category 3. Eolian: Sand Dunes

Category 4. Eolian: Loess

Category 5. Fluvial: Flood Plains

Category 6. Fluvial: Deltas

Category 7. Fluvial: Alluvium (Fans, Valley Fills; Continental)

Category 8. Fluvial: Playas (Arid Lake Beds)

Category 9. Fluvial: Organic (Swamps, Bogs, Marshes)

Category 10. Fluvial: Coastal Plains

Category 11. Fluvial: Beach Ridges

Category 12. Fluvial: Tidal Flats

Category 13. Fault

**Map 7.1 Topographic Elevation (Part 1 of 3)**

This database contains areas which have the *thousands* of feet digit stored.

Category 1. 0000's

Category 2. 1000's

Category 3. 2000's

Category 4. 3000's

Category 5. 4000's

Category 6. 5000's

Category 7. 6000's

Category 8. 7000's

Category 9. 8000's

Category 10. 9000's

Category 11. 10,000's

Category 12. 11,000's

Category 13. 12,000's

Category 14. 13,000's

Category 15. 14,000's and above

**Map 7.1 Topographic Elevation (Part 2 of 3)**

This database contains areas which have the *hundreds* of feet digit stored.

Category 1. 000's

Category 2. 100's

Category 3. 200's

Category 4. 300's

Category 5. 400's

Category 6. 500's

Category 7. 600's

Category 8. 700's

Category 9. 800's

Category 10. 900's

**Map 7.1 Topographic Elevation (Part 3 of 3)**

This database contains areas which have the *tens* of feet digit stored.

Category 1. 00's

Category 2. 10's

Category 3. 20's

Category 4. 30's

Category 5. 40's

Category 6. 50's

Category 7. 60's

Category 8. 70's

Category 9. 80's

Category 10. 90's

**Map 7.2 Topographic Slope**

Category 1. Water

Category 2. Flat Land

Category 3. .1% to 1%

Category 4. 1% to 3%

Category 5. 3% to 5%

Category 6. 5% to 7%

Category 7. 7% to 9%

Category 8. 9% to 11%

Category 9. 11% to 13%

Category 10. 13% to 15%

Category 11. 15% to 20%

Category 12. 20% to 25%

Category 13. 25% to 35%

Category 14. 35% to 45%

Category 15. Greater than 45%

**Map 7.3 Topographic Aspect**

Category 1. North

Category 2. North North East

Category 3. North East

Category 4. East North East

Category 5. East

Category 6. East South East

Category 7. South East

Category 8. South South East

Category 9. South

Category 10. South South West

Category 11. South West

Category 12. West South West

Category 13. West

Category 14. West North West

Category 15. North West and North North West

(Category 16. Blank = Flat or Water)

**Map 8.1 Wildlife and Flora**

Category 1. Animal--Year Around--Rare, Endangered, or Threatened

Category 2. Plant--Year Around--Rare, Endangered, or Threatened

Category 3. Animal--Seasonal--Rare, Endangered, or Threatened

Category 4. Game Animals

Category 5. Game Birds

Category 6. Game Fish

Category 7. Openland Wildlife--Animals

Category 8. Woodland Wildlife--Animals

Category 9. Wetland Wildlife--Animals

Category 10. Rangeland Wildlife--Animals

Category 11. Notable Terrestrial Plants

Category 12. Notable Aquatic Plants

Category 13. Nonnative Biology

**Map 9.1 Noise Zones**

Category 1. Zone 1-C-Weighted, Below 62  
Decibels

Category 2. Zone 2-C-Weighted, 66 to 70  
Decibels

Category 3. Zone 2.1-C-Weighted, 62 to 65  
Decibels

Category 4. Zone 2.2-C-Weighted, 66 to 70  
Decibels

Category 5. Zone 3-C-Weighted, Greater Than  
70 Decibels

Category 6. Zone 1-A-Weighted, Below 65  
Decibels

Category 7. Zone 2-A-Weighted, 65 to 75  
Decibels

Category 8. Zone 3-A-Weighted, Greater Than  
75 Decibels



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